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ACCUMULATION OF MERCURY VAPOR IN SOILS LABORATORIES¹

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Abstract

The rate of accumulation of mercury vapor in a closed room was determined as a function of surface area of the exposed mercury, ambient temperature, and air flow. The rate of mercury vapor accumulation was much higher than suspected by many soil scientists. For example, in a 3- by 3- by 2-m constant temperature room, 250 cm² of mercury surface produced toxic levels of mercury vapor within 13 minutes. Water or oil covering the surface of the mercury was a highly effective means of suppressing vaporization. The standard decontamination treatment with sulfur proved effective, but only after complete amalgamation occurred.

Additional Key Words for Indexing: maximum allowable concentration, oil, water, sulfur amalgamation.

BECAUSE of its widespread use, soil scientists should be aware of the toxic characteristics of mercury. There

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are two types of mercury poisoning, acute and chronic. While acute poisoning is usually the result of ingestion of soluble mercury salts, chronic poisoning is produced by the human body's ability to absorb mercury faster than it can be eliminated, producing a less severe form of poisoning. Chronic mercury poisoning is usually the result of absorption of metallic mercury or its vapor through the hands or respiratory tract although mercury can be absorbed through all body surfaces.

In soils laboratories, the major concern is chronic mercury poisoning, whose classic symptoms are coarse tremors and erethism (emotional instability and lability), salivation, fine tremors, and bleeding gums. Chronic poisoning is best treated by removal from exposure to the source of mercury (6).

The most common source of chronic mercury poisoning is the inhalation of mercury vapor produced when mercury evaporates at room temperature. The vapor pressure of the metal increases from 0.0012 mm Hg at 20C to 0.0028 mm Hg at 30C, which, coupled with the large surface area produced when spilled mercury shatters, produces rapid vaporization (4).

The United States Public Health Service and American Standards Association have set the maximum allowable concentration (MAC) of mercury vapor in air at 0.1 mg/m³ of air. However, there is no agreement among investigators, since some state that a concentration of only 0.00057 mg/m³ of air will result in symptoms of mercury poisoning after an 8-hour exposure. Persons who have

an allergenic reaction to mercury may be particularly sensitive to low levels of mercury vapor in the air they breathe (2).

Because mercury vapor is almost undetectable, being colorless, odorless, and tasteless (except in very high concentrations when it may cause a metallic taste in the mouth), industrial hygienists have developed a series of precautionary measures to be taken during the handling of mercury, such as outlined by Lawrence (5). Mercury should be handled as a Class D poison similar to radioactive sources and the precautionary measures are almost identical.

Soil scientists frequently use mercury-filled instruments in work areas having limited external ventilation. Consequently a study was undertaken to measure mercury vapor concentrations under these conditions.

Materials and Methods

The experiments were conducted in a 3- by 3- by 2-m constant temperature room containing circulating fans and a temperature controller to maintain the temperature within $\pm 1^\circ\text{C}$. Containers of mercury exposing various surface areas were placed in the room, and the mercury vapor concentration monitored through a transparent port in the wall. A Beckman Instruments K23 mercury vapor detection meter was used to determine the level of mercury vapor in the air. (Trade names and company names are included for the benefit of the reader and do not infer any endorsement or preferential treatment of the product listed by the USDA.)

In these tests, the time interval was measured between placing the mercury sample in the constant temperature room and the time the mercury detection meter indicated a vapor concentration of 0.1 mg/m^3 (MAC). This is an indication of the potential hazard to an experimenter working in an enclosed space such as this.

The effects of surface area, temperature, air movement, and decontamination treatments on the time to reach MAC in the room were evaluated. Seven nonmetallic containers of known surface area ranging from 81 cm^2 to 380 cm^2 were used in

three different temperature ranges: $14\text{--}16^\circ\text{C}$, $22\text{--}24^\circ\text{C}$, and $29\text{--}31^\circ\text{C}$.

The circulating fans in the room were turned off and the influence of air movement on the rate of vaporization of selected samples was determined.

The effectiveness of covering the surface of a given sample of mercury with both oil and water was evaluated over a period of 96 hours.

To determine the effectiveness of the standard procedure of amalgamating spilled mercury with sulfur, two treatments were used. In the first, partial amalgamation was effected by treating the surface of a 1-cm deep mercury sample. Complete amalgamation was produced in the second treatment by dropping approximately 10 g of mercury into a tray and treating the globules produced with sulfur. This dust was removed after the first series of tests to determine if its presence affected the results observed.

In all decontamination treatments except partial amalgamation, the level of mercury contamination in the room was monitored for up to 96 hours following the introduction of the sample into the room. Partial amalgamation was evaluated in the same manner as the effect of surface area.

Results and Discussion

The effects of both surface area and temperature on the time necessary for the atmosphere in the constant temperature room to reach the maximum allowable concentration of mercury vapor are summarized in Fig. 1. The scatter of data points in Fig. 1 was probably due as much to drift in the DC-coupled amplifier in the mercury vapor meter as to any physical change in the experimental environment.

When the surface of the mercury was treated with either oil or water, the survey meter failed to detect any contamination from mercury vapor at the end of the 24-hour period following the application of the treatment. Each of these treatments was replicated twice with the same negative results.

When the circulating fans in the room were shut off, the rate of evaporation of pure mercury decreased 10-fold. With the fans in operation, the selected sample of mercury took approximately 6 min to contaminate the entire volume of air. With no air circulation, the same sample took approximately 40 min to produce the maximum allowable concentration at floor level with a slight decrease to 0.07 mg/m^3 at the ceiling.

Partial amalgamation of the sample increased the time for the sample to produce a MAC only slightly, to about 45 min. No further increase was noted over the duration of the monitoring period. This indicates that mercury vapor was apparently diffusing through the layer of amalgam from the pure mercury below.

Complete amalgamation of the mercury globules with sulfur drastically reduced the amount of mercury vapor released into the air. Twenty-four hours after the sample was placed in the room, the level of mercury vapor in the air was only 0.03 mg/m^3 of air and remained at this level for the next 2 days. Apparently there was enough air exchange with the air outside the room to prevent the concentration from going any higher.

Both partial and complete amalgamation tests indicated that the maximum effect of the sulfur treatment was achieved 24 hours after application.

The results of these tests indicate the conditions which

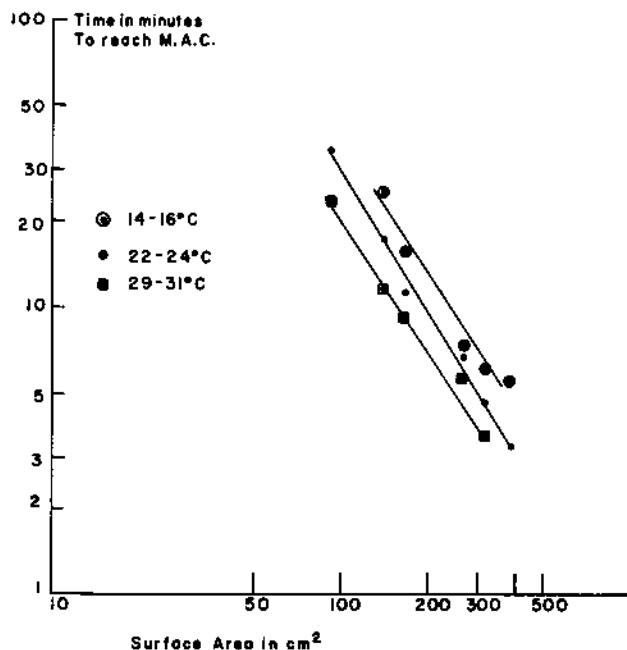


Fig. 1—Temperature dependence of mercury vaporization.

must be considered in using sulfur powder to reduce mercury contamination. Large masses of mercury must be removed before treatment to minimize the total amount of metal present and afford more intimate contact between the mercury and the sulfur. Sulfur is no substitute for good housekeeping. Amalgamation of the mercury with the sulfur must be almost complete in order for this treatment to be effective. Even in its amalgamated state, the mercury will produce a low-level contamination of the atmosphere. Sulfur does not eliminate the contamination, it merely slows the rate of release of mercury into the air (1, 3). If this low-level concentration of mercury vapor produced by the sulfur-mercury amalgam is not acceptable, then more radical decontamination methods must be utilized (7).

During the course of this work, an opportunity arose to monitor the mercury vapor concentration and evaluate the effectiveness of the sulfur dust treatment in a laboratory where the metal had been spilled. In the main laboratory area where the sulfur treatment had been used, particles of metallic mercury were visible in the cracks between the floor tiles, but the air 10 cm above the surface of the floor showed no mercury contamination. On the other hand, in the storage area where some mercury had been spilled there was no metallic mercury immediately visible, yet the mercury vapor level at floor height was 0.02, and negligible at breathing level early in the morning before any traffic occurred in the storage area. After a few minutes of walking about in the room, these levels rose to between 0.07 and 0.15 mg/m³ at floor level, and 0.03 at the breathing level. Apparently accumulated dust, oil, oxide, amalgam, and floor wax on the surface of the mercury in the floor of the main laboratory was suppressing the production of mercury vapor, whereas the accumulation of mercury in the storeroom needed only sufficient mixing of the air to produce significant levels of contamination.

Conclusion

Mercury vapor accumulates in closed areas such as constant temperature rooms at a rate much higher than suspected by many workers. A person working in one of these rooms with a surface area of mercury equal to the surface area of the bottom of a 1,000-ml beaker exposed for vaporization may be working in an atmosphere containing the maximum allowable concentration of mercury vapor in approximately 35 min. If the surface area of mercury is increased to one equal to the bottom of a normal sized water bucket, only 3 to 4 min are required before the maximum allowable concentration of mercury vapor is reached. Water or oil covering the surface of the mercury and preventing its contact with the air effectively eliminates all contamination from mercury vapor. Treatment of mercury with sulfur powder is effective only if complete amalgamation of the sulfur and mercury is affected, and even then merely reduces the level of contamination but does not eliminate it entirely.

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